A SPECTRAL-ELEMENT METHOD FOR MODELING CAVITATION IN TRANSIENT FLUID-STRUCTURE INTERACTION: 3-D EVALUATION

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When simulating underwater shock problems near a free surface where the charge is sufficiently removed from the structure, the fluid can be modeled with Cavitating Acoustic Finite Elements (CAFE) [1] that are coupled to a finite-element model of the structure. However, it has been demonstrated that the CAFE approach is too computationally expensive for realistic 3-D problems [5]. Recently, CAFE has been improved by (*i*) separating the total field into equilibrium, incident, and scattered components, (*ii*) replacing the bilinear CAFE basis functions with high-order Legendre-polynomial basis functions, which produces a cavitating acoustic spectral element (CASE) formulation, (*iii*) introducing a simple, non-conformal coupling method for the structure and fluid finite-element models, and (*iv*) introducing structure-fluid time-step subcycling [6].

We evaluate the performance of the CASE implementation by calculating the response of an empty submerged spherical shell excited by a spherical step-exponential wave. We investigate the shell's response with and without cavitation effects; in the absence of cavitation the problem has an analytical series solution [4]. The performance of CASE discretization is compared with CAFE discretization in terms of the number of fluid degrees of freedom needed for a given level of accuracy, as well as associated memory-storage and operation requirements. It is demonstrated that CASE admits marginal savings in required fluid degrees of freedom, but admits significant savings in memory storage requirements when compared with CAFE. These savings, along with ease of parallelization, make CASE the preferred discretization method. It is also demonstrated that accuracy can be greatly improved through the use of field separation.

Using the CASE approach, we calculate the response of a box representation of a modern frigate to an underwater explosion. Here, the incident field is quasi-acoustic, and is produced with the Geers-Hunter bubble model [2] and the Hunter-Geers field model [3]. It is demonstrated that sufficient fluid refinement can be achieved with manageable computational cost. Finally, the model is used to demonstrate that the fluid mesh can be substantially truncated before accuracy is sacrificed, which yields further computational savings.

References

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